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ABSTRACT

Curriculum designers have derived data for instructional purposes from 1) the subject matter, 2) society, and 3) the learner. The computer plays an instrumental role in individualizing the presentation of curriculum derived from these sources. Research on instruction has concerned itself with devising material for individual needs and adapting them to meet the necessities of group instruction. Computer assisted instruction, computer managed instruction, and simulation programs have been developed for a wide variety of subjects. Another significant development in curriculum design has been the systems approach. The systems approach uses the tools of task analysis and behavioral objective statements to design an individualized instructional strategy. A consideration of national and regional manpower requirements, combined with content analysis of a total curriculum is but one approach to developing a dynamic curriculum. Interactive empirical procedures seem to produce more effective instructional materials. In order to minimize costs of a computer facility, regional computer networks have been established on a n experimental basis. A list of references is appended. (JY)

THE COMPUTER AND CURRICULUM ANALYSIS

For presentation at the Organization for Economic Cooperation and Development, Center for Educational Research and Innovation Conference on "The Instructional Uses of Computers in Education" Paris, France

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Summary

Today a wide array of scientific social and technological developments are reshaping society and with it the course of modern education. The scientific information explosion, rapid access to social events through modern telecommunications and the trend toward equal opportunity to education are affecting American education and altering what we teach and how we teach it.

Historically, curriculum designers have derived their data for instructional purposes from three sources 1) the subject matter 2) society and 3) the learner. Today, there is a strong trend toward presenting curriculum derived from these data sources in a manner designed to meet the needs of the individual student. The computer is playing an instrumental role in the efforts to achieve this goal. Among educators, considerable attention is being given to the process of defining learning goals and stating them in behavioral or performance terms. Research on instruction has concerned itself with devising materials for individual needs and adapting them to meet the necessity of group instruction. The computer is fast becoming a significant tool in implementing the individualization of instruction. Computer-assisted instruction, computer-managed instruction and simulation programs have been developed for a wide variety of subjects.

Probably one of the most significant contributions of the new educational technology is the application of the systems approach to curriculum development. The use of national and regional manpower requirements combined with a content analysis of a total curriculum is but one approach to designing a dynamic curriculum to meet the needs of a rapidly changing world. System techniques such as task analysis and procedures for stating behavioral objectives are important tools for designing an instructional strategy to meet individual needs. While the "empirical iterative" approach to the design of instruction materials is a departure from the traditional learning theory approach to instruction, it is considered a good interim model to curriculum design and is capable of producing effective, reliable educational results. Due to the time and expense of developing instructional computer programs, cooperative efforts are being undertaken on a regional basis to reduce costs and improve the effectiveness of instructional materials. Fifteen regional computer network experiments have been initiated and are serving as models to assess the role and costs of computing activities in American education.

I. Factors Affecting Education.

Today a wide array of scientific, social and technological developments are reshaping our society and with it the course of modern education. Education, after all, is based upon the values of a society and as the values change so do the goals of education.

The scientific information explosion has had significant implications for education in general and curriculum designers in particular. The body of recorded scientific and technical information is increasing exponentially and can be expected to double in the next 12 years.[1/] New information and the pace of discovery has given rise to new disciplines and has made others obsolete. The complexity of the problems studied today has required inter-disciplinary approaches and has made it necessary for scientists to acquire skills and knowledge in more than one discipline. The rapid increase in knowledge has paralleled by a rapid change in educational problems. It is projected that the new graduate from a professional school will have several professions in his lifetime. It is estimated that 70% of the children in elementary schools will work in an occupation that does not exist today.[2/] The static disciplinary curriculum of the past is yielding to a more dynamic, interdisciplinary one of the present.

Social factors have influenced the organization and structure of education as well as what is to be taught. We live in a communications age. Modern telecommunications has brought the happenings of the world into the living room of every family. Over 95% of the families in the United States have a television set. At the current rate of viewing, it is estimated that the average American youth will spend more time in front of his television set than he will in the classroom. This has lead to a student insistence that education be more relevant to today's social problems. The more worldly student desires learning and not schooling. A new social awareness has created new demands for education.

Another significant factor is the trend toward a greater democratization of education--providing education for all. It has been recognized that, although education is open to all, that certain economic and social conditions frequently preclude the full participation of all.

In the United States attempts are being made to remove the economic and social barriers to education and to create equal opportunity. Open admission in state and community colleges, loans, scholarships and aid to educational institutions has lead to greater numbers of students entering higher education. With an every increasing number of students with heterogeneous backgrounds, skills and

abilities, universities are assuming a new responsibility for the performance of their students. In the past teachers taught and students passed or failed. Today, students come to learn and it is school systems that pass or fail. As the base of college students changes from a highly selective group of 3% of the nation's population who are professionally oriented to a broader base of some 60% or more with a wide diversity of interest, educational functions and purposes will have to be reconsidered and reoriented. Education is being tailored to meet the needs of the individual. The formal boundaries of discipline, educational level and curriculum are melting away to be replaced by individual goals and personalized curriculum.

II. Educational Curriculum Development

Historically, curriculum in American education was organized around the academic discipline and changed slowly with major changes occurring but once every generation and more recently once every decade. In the past, many forces have come to determine the make-up of new curriculum. Scholarly groups through national curriculum commissions in various professions or academic disciplines, popular social movements, foundations and governments have provided the stimulus for change. McNeil [3/] in a review of the forces influencing American curriculum identifies three major sources for the formulation of instructional objectives:

1. Subject matter as a data source. A review of curriculum development indicates that designers and practitioners tend to construct curriculum in accordance with definitions of the structure of various disciplines as determined by scholars who specialize in a given field. Since the latter part of the 19th century, curriculum making by national committees has been a distinctive feature of American education. [4/] The Committee of Ten in 1893 and the Commission on the Reorganization of Secondary Education in 1918 were early attempts to change in high school curriculum. More recently national professional organizations and academic disciplines have designed curricula such as School Mathematics

Study Group (SMSG) in 1958 and The Biological Sciences Curriculum Study (BSCS) during 1959-1964.

2. Society as a data source. Another data source for curriculum development has been derived from studies of contemporary life. Analyses have been made of professions or jobs and mastery of skills actually employed and they have become the objective of a training program. Some studies have focused upon job families or clusters of skills and knowledge which are closely related.

3. Learner data as a source. Curriculum have been designed to help the learner explore and develop his interests. Based upon his need and interests, instruction has been designed to satisfy the individual learner's goals.

Today, there is a strong trend toward presenting curriculum derived from these data sources in a manner designed to meet the needs of the individual student. The computer is playing an instrumental role in efforts to achieve this goal.

III. The Computer and Individualized Instruction

Cooley and Glazer define individualized education as the adaptation of instructional practices to individual requirements.[5/] They maintain that three factors are involved 1) educational goals, 2) individual capabilities and 3) instructional means. They define goals as those which suit the individual when individuals choose different courses of instruction for different vocations. Individual capabilities refer to the capabilities that the individual brings to a particular instructional situation and instructional means include what is taught and how it is taught. Cooley and Glazer say the instructional model operates in the following sequence.

1) The goals of learning are specified in terms of observable student behavior and the conditions under which this behavior is to be manifested.

2) When the learner begins a particular course of instruction his initial capabilities--those relevant to the forthcoming instruction, are assessed.

3) Educational alternatives suited to the student's initial capabilities are presented to him. The student selects or is assigned one of these alternatives.

4) Instruction proceeds as a function of the relationship between measures of student performance, available instructional alternatives, and criteria of competence.

5) As instruction proceeds, data are generated for monitoring and improving the instructional system.

Various degrees of automation can be used to implement the model. However, it is possible to implement such a system without automation. With a redesign of the school organization, appropriate tests and materials, teacher aides can carry out individualization of instruction. A computer can be introduced to assist the teacher in assessing the student's capabilities and prescribing a course of instruction. "Computer-managed instruction" (CMI) assists the teacher and student in planning instructional sequences and may refer the student to self-instruction packages or more conventional instruction. The student can use the computer as a means of instruction directly through "computer-assisted instruction" (CAI). Individualization can operate in any of these three modes--manual, CMI or CAI.

1. Educational Goals. The specification of educational goals is a complex problem. Cooley and Glazer maintain that the educational technologists does not set the goals for American education but instead his task is to identify goals that are valued in his society and then develop procedures for achieving them.

The stating of instructional goals or objectives and the establishment of performance criteria in behavioral terms has become a central theme among modern curriculum designers. The "Taxonomy of Educational Objectives," by Bloom, Krathwohl and others have influenced the formulation and classification of learning objectives. 6/ 7/ Mager's "Preparing Objectives for Programmed Instruction" provided a means for writing behavioral objectives as a form of criterion measure. 8/ Tyler observes that there are sharp differences in the formulation of objectives and conditions for learning by theorists. There are those who perceive the learner as being "conditioned" by the learning situation so as to respond in the way specified by the teacher or designer of the program and there are those who perceive the learner as an active agent exploring learning situations so as to learn to manipulate them for his purposes. 9/ Who controls the learning situation--the curriculum designer, the teacher or the student--greatly influences how objectives are formulated and specified and ultimately, the design of the curriculum and the learning environment.

2. Individual Capabilities. Briggs 10/ points out that educators have long sought ways to adapt group methods of instruction so that all children in the group progress at acceptable rates and reach satisfactory levels of achievement in reasonable amounts of time.

He says it is not surprising that group teaching methods with some fixed set of materials normally fails to achieve this purpose. He argues that attention should be focused on learning variables--why the person does or does not meet the criteria of progress. Only then can insights be gained into what the individual learner needs in the way of instructional materials or media. We should then consider how this need can be met in spite of the necessity of group instruction. He argues that it is working backwards to ask first whether one should prefer to use ability grouping or branching programs without first determining what the student's needs are.

Gagne and Paradise 11/ suggest that differences in rate of learning are due not to variations in general ability to learn fast, but rather to (1) the number and kinds of learning sets (competencies, knowledge) the learner brings to the situation, (2) his standing in respect to certain basic abilities relevant to the competencies to be acquired as they are identified in the theoretical hierarchy for the task and (3) his level of general intelligence. Therefore if a student fails to perform after a learning program; this due to a) some subordinate knowledge which may have been left out of the program b) insufficient practice or c) some other program characteristic may have resulted in poor recall of a subordinate competency or d) the program may have been defective in guiding

the thinking required to induce the necessary integration of subordinate competencies.

A second consideration is individual differences in rate of learning. Briggs[10] says that it is apparent that just pushing the learner through the program faster is not always a good way to improve learning. On the other hand, self-pacing by the learner is not a universal cure for slow learning.

Individual differences in the rate of learning for computer-assisted instruction are far larger than previously thought. Therefore, he recommends the general rule that when individual learning is progressing faster than forgetting the experimenter should show all of the material on the first trial. But when forgetting is faster than learning, only one item at a time should be presented.

When considering branching as a means of individualizing instruction, Briggs points out that while on the face of it branching should be superior to linear presentations because it reduces superfluous information presented to the learner, research findings do not support the contention that branching is superior to linear programs.

Briggs finds many conflicting positions when it somes to specifying the size of the step to be used in learning programs. He summarized the position of a number of learning theorists over the size of the step to be used.[12] Briggs says that B. F. Skinner

recommends that small steps be used. Jerome Bruner has suggested that huge leaps, with occassional small steps is the optimum approach. Joseph Scandura recommends abandoning the S-R bond as the basis unit in learning and even questions the relevance of learning theory as a basis for a theory of instruction. In its place he would substitute "principles." Sidney Pressey objects to the fractionization of learning into small steps and proposes larger, learner-determined, flexible size steps. David Ausubel advocates the use of introductory statements in the most general, abstract form to serve as aids to cognitive structuring of subsequent material. Briggs concludes that new techniques are needed to permit the learner to adjust step size to his capabilities without suffering either from making many errors or tedious unneeded redundancies.

Briggs feels that the value of empirical methods of developing instructional materials, emphasized heavily by programmers, is coming to be thought of by many as the greatest permanent effect of the programmed instruction movement. And in general, the procedure of task analysis, empirical tryout by sequencing studies to validate or correct the task analysis, followed by further empirical revision is a good interim model to follow until we have more refined theories of task taxonomies, learner variables, and media variables.

After a review of the theoretical research literature on programmed instruction, Gentile[13/] concludes that there is a specialized theoretical approach which investigators are pursuing. They are focusing upon specific learning situations and developing quantitative models which when related to optimal instructional sequences can be used to maximize learning. Gentile maintains that investigators are building curricula on the basis of specific models of learning process within a given subject matter. Their instructional sequences become hypotheses of optimal learning. The curriculum is viewed as a theoretical statement of the best way to learn the subject matter. As such it is to be tested experimentally and changed accordingly.

Gentile raises the question as to whether teachers should be urged to adapt to individual differences. If the teacher has a standard plan well fitted to the average of the group should he be asked to depart from it? Gentile says that marked departures from the plan should only be advised when individual differences are validly assessed and their implications for treatment are clear. Until individual difference variables are demonstrated, programming energy might best be expended in the development of one good program aimed at the mean of the population. For those who would object Gentile offers two counter-points: "First it has yet to be demonstrated that branching sequences which are unique to criteria based on individual differences produce superior learning to some

other simpler remedial technique, such as repetition of the difficult frame sequences. Second the burden of proof rests with those who would replace existing teacher techniques with CAI systems."

3. Instructional Means. The computer is fast becoming a significant tool for instruction. Many major universities are developing courses with the computer as an integral part of the curriculum. High schools, vocational schools as well as business and industry are using the computer for instructional purposes. Computer-assisted instruction programs exist for physics, chemistry, mathematics, digital computing, engineering, English, French, Spanish, Russian, Chinese, psychology, statistics, economics, management science, medical and biological sciences and many others.[14/] [15/] [16/] A recent survey of CAI programs lists 226 programs developed by 160 authors at 38 centers in 34 computing languages for 35 different machines.[17/]

A. Computer-Assisted Instruction (CAI). There are a number of centers conducting research in computer-assisted instruction. Some of these are: The University of California at Santa Barbara and Irvine, Florida State University, Harvard, The University of Illinois, Pennsylvania State University and The University of Texas.

One notable effort in computer-assisted instruction is the Stanford University Institute for Mathematical Studies in the Social Sciences. In 1965 the Institute began its drill and practice program using a time-sharing system on the PDP Central Processing Unit at Stanford Computation Center.[18/] Starting with one terminal

and 41 students and operating off a PDP-1 system it now services 3,000 students per day in mathematics programs, programs in spelling drill, Boolean algebra, logic and Russian and a program for teaching of computer programming. Telephone lines provide nation-wide service for schools as far away as Mississippi. In addition, beginning with the IBM 1500, computer-assisted instruction was provided for reading and first and second grade mathematics. Now the current system operates off a PDP-10 computer at the Stanford Computation Center and provides daily services in reading and mathematics, using 46 teletype terminals, for 1400 students. In the reading program 18 of the terminals are equipped with digitized audio and services more than 400 students per day.

The computer based Russian program was designed to teach first and second year college level courses in comprehension of spoken Russian and the mastery of grammar and syntax.[19/] The course has three components: 1) computer sessions, 2) the use of a language laboratory tapes and 3) homework assignments. The CAI students spend about 50 minutes a day, five days a week using a combined audio and teletype format. The teletype keyboard was modified to use a Cyrillic alphabet.

A tutorial program has also been developed in elementary logic and algebra.[20/] It is primarily concerned with numerical and sentential variables, formation of algebriac terms and sentences

and truth conditions of simple sentences. Logical connectives and the rules of derivations are presented. Rules of logic and some algebriac rules and concepts of validity of rules and validity of arguments are also included. The second year of the program is concerned with modern algebra. The student works from a small set of axioms and rules of inference develops the properties of the field of rational numbers. The student also proves some elementary theory for addition, multiplication and ordering.

The elementary school mathematics program is based upon 24 concept blocks or units for each grade level. A block is comprised of lessons for seven days work and are arranged sequentially to correspond to presentations in popular tests. The student's first day lesson in each block is a pretest on the basis of which the computer assigns one of five lessons of varying difficulty for the following day. The student must obtain 80% or higher on each drill before he is permitted to proceed to the next level of difficulty. If a student received a score of less than 60% he would be branched down to the next lower level of difficulty, and if he is between 60% and 80% he remains at the same level. The final day is reserved for a post-test. In addition to drill lessons individual reviews selected from previous blocks are also presented. The drill lessons take from two to ten minutes to complete and students are expected to do at least one per day. The drills include both verbal and numerical exercises.

The concept blocks can be arranged to correspond to the sequence of topics in various text books, they can also be adjusted by grade level and for each grade level there are lessons for five levels of difficulty. The computer automatically matches presentations to student performance and provides reinforcement through immediate feedback to student response. Students may proceed through the materials as rapidly as they wish. These adjustments insure that poorer students as well as students of high ability can have successful learning experiences.

The reading curriculum was based upon the assumption that the two major aspects of reading are communication (reading for meaning, aesthetic empathy, enjoyment, etc.) and decoding. It was felt that the communication aspect of reading could best be presented in the classroom by a human teacher in some dialogue mode, and the decoding aspect could best be presented by a computer in a drill or practice mode. Also, it was assumed that in learning to read associations must become habits so automatic that graphic shapes themselves sink below the threshold of attention and that this could best be accomplished by repetitive presentations for short intensive drill periods with the immediate knowledge of results.

The current curriculum is a carefully constructed program based on the most frequently used vocabulary in major reading texts and sight-word lists. The program is divided into six strands or basic component skills of initial reading: 1) letter identification

2) sight-word vocabulary 3) phonics 4) spelling patterns 5) comprehension and 6) language arts. A strand is defined as a series of problems of the same operational type arranged sequentially in classes according to their relative difficulty. A student proceeds through strands in a linear fashion and progresses to a new exercise within a strand only after he has met an individually specifiable performance criterion on the exercise.

Entry into each strand is dependent upon a student's performance in earlier strands; however, a student may work in several strands simultaneously. Once in a strand, however, his progress is independent of progress in other strands. Studentsspend two minutes in each strand and eight minutes total per day. Instructions are given in a digitized audio message. There is a vocabulary of 5000 sounds which are recorded and stored in digital form on the computer's magnetic disk.

B. Computer-Managed Instruction (CMI). Computer-Managed Instruction differs from CAI in that in CMI students records and profiles are kept stored in the computer and the student enters a test or examination. The results of the test are recorded and evaluated against previous data and a prescription is printed out which directs the student to new materials such as a concept film or a lesson or the computer may provide him with remedial work to improve a detected weakness. The aim here is to design a curriculum

for the unique characteristics and needs of the individual and to provide constant feedback to him on his progress. The information is used to pace the student, group students, and to sequence instruction materials. The CMI program is primarily designed to assist the teacher in planning an instructional strategy. It has the flexibility of using material which may or may not be stored in the computer and takes advantage of other multimedia forms. Unlike CAI, CMI does not require a large number of terminals for the student is not necessarily on line with the computer and the instructional materials are presented in a conventional manner.

Silberman[21/] in a review of CMI describes the System Development Corporation's Instructional Management System (IMS) which was developed with the Southwest Regional Laboratory and is used in the Los Angeles School System. Tests are given children in which each item is keyed to a teaching objective. The test data are fed into the computer and programs relate student response data to instructional objectives and designate appropriate prescriptive information. If the teacher wants additional diagnostic information or information about materials she can use the teletype terminal to make additional queries.

A similar system, Individually Prescribed Instruction (IPI), is being used in the Oakleaf School in Pittsburgh, Pennsylvania. The system is like IMS except that the teacher inscribes the performance data on machine-readable forms which permits wider range of behavior to be recorded. They also differ in that IPI is a completely

individualized instruction system while IMS attempts to accommodate individualized instruction while operating with grouped instruction. Both IMS and IPI are using IBM machines with 1232 optical scanning equipment.

It was reported in a study by Research for Better Schools (RBS) that on standard achievement tests IPI students do as well as non-IPI students.[22/] It was also noted that standard achievement tests do not adequately measure IPI programs since IPI skills are not tested by standard normative referenced achievement tests (less than 30%). They point to the need for the design of new tests which are criterion referenced tests as opposed to normative referenced. Based on interview data, IPI students like school better than non-IPI pupils. Surveys indicate that teachers are highly favorable toward IPI programs and derive satisfaction from guidance role in learning rather than being dispensers of information. To date 110 studies have been conducted on IPI as an instructional system. Approximately fifty of these studies are presented in summary form and the remainder in an annotated bibliography in the RBS report.

Silberman reports that Program for Learning in Accordance with Needs (PLAN), which is being developed by the American Institutes for Research and the Westinghouse Learning Corporation and 14 cooperating school systems, uses instructional units which are related to instructional objectives. The units are prescribed on

the basis of current student performance and learner characteristics as measured by aptitude tests. The instructional units are broader activities (textbooks, audio-visual material, group projects or tutoring) than those contained in the more detailed prescriptions of the IPI or IMS systems.

Another project which is using a CMI approach is being carried out at the New York Institute of Technology. It includes college level courses in mathematics, physics, electronic technology and computer sciences.

The Teacher's Automated Guide (TAG) is being developed by the Portland Oregon Schools and is a system which permits the storage and retrieval of lesson plans by computer. The teacher inserts a number which represents a given objective and receives a display of the lesson plans appropriate for teaching that specific objective.

C. Simulation. Simulation is also another effective use of computer instruction. In simulation a model of the real world environment is created either in replica or in some analogue form. Simulation eliminates many irrelevant characteristics unrelated to learning and complex situations are often simplified so that the student can grasp complex relationships. Time dimensions can be compressed so that events which take many years to transpire in the real world can be presented in weeks or events which occur in very short periods of time can be expanded so that

the student can observe the complete relationships. Dr. Stephen Abrahamson[23] at the University of Southern California has developed a computer simulation with a dummy having realistic human features for teaching the effects of drugs on body functions. One advantage of such simulations is that medical students studying anesthesiology can practice and learn under realistic conditions without danger or discomfort to a live patient. Economic simulation games have been developed to teach the dynamics of complex social relationships.[24] Simulated laboratories also permit students the opportunity of carrying out laboratory experiments without the necessity of going to the laboratory to actually conduct the experiments.

IV. The Systems Approach.

Rosenstein and Cromwell[25] point out that the problem of education is that the curriculum must be designed to assist the student to face problems which will occur ten to twenty years in the future. This would be a relatively simple problem in a static society. But as major social values shift within society and as rapid technological and informational change takes place there are recurring lags between the output of education and the potential input. The constant change of faculty interests and assignments requires the existence of a convenient vehicle to capture and transmit the content of the curriculum to the changing membership of the curriculum committees. There is need to view both the overall form and effect of the curriculum as well as its detail content. The curriculum designer needs to know what material is provided in the curriculum; the depth of presentation; the degree of existing redundance; the time required to present each item and the actual time allowed; the prerequisites for each item and the dependent material in subsequent courses.

In an analysis of the University of California at Los Angeles engineering undergraduate curriculum, Rosenstein and Cromwell found that Hookes' Law had been taught seven times and each time as though it had not been taught before. While planned redundance and reinforcement is considered important in effective learning, random unplanned redundance is a major source of inefficiency.

They content analyzed the curriculum and in their evaluation for redundancy found that only 41.5% of the topics were actually different. They also found that one-third of the items of the engineering program were presented by definition.

To be really a dynamic curriculum they say, feedback must be provided on a regular basis--every two years. They point out that curriculum data maintenance demands a continuing investment. They recommend that professional societies should cooperate to institute surveys on a regular basis to determine national and regional requirements for the projected needs of the society to be satisfied by the professions and the requirements for professional men by type, quantity and educational level. Surveys of the practicing professional should be conducted with regional support to furnish the national career profile of practicing professionals and to allow local correlations between the career profiles of an institution's graduates and the effectiveness of past curricula. Finally professional schools should allocate 3% to 4% of their faculty time to research upon quality control of their educational product. They propose computer programs for the storage and retrieval of all curriculum information.

A. System Techniques. In the development of the CAI physics curriculum, Duncan Hansen of Florida State University used a systems approach.[26/] First, a description of the instructional problems was made and concurrently a task analysis of the conceptual requirements as well as the behavioral processes was

performed. An assessment of the entry skills and prior knowledge of the student population was made. This resulted in a set of behavioral objectives which formed a description of the criterion performances desired as outcomes for the student. The behavioral objectives were sequenced and structured into instructional strategies for given segments within the course. Media and instructional contexts were selected prior to the field test. The empirical results from the field test provided the basis for the evaluation of the minimal materials and were used for subsequent revisions.

1. Problems Identification. Four techniques were used for problem identification. First a literature search of physics education was made to determine information about student needs and prerequisite abilities. Second, conferences were held with faculty to identify conceptual development of the material, associated problem skills and problems with student motivation. Third, prior test results over a three year period were studied. Finally, difficult conceptual problems were used to develop a set of problems which were administered to a sample of students in conventional courses. This provided baseline data for comparison during the development of the CAI problems.

2. Task Analysis. A video recording was made of 29 conventional classroom lectures and demonstrations. This provided insight into language appropriate for instruction and

pedagogical techniques used by more successful professors. Secondly, four currently popular physics textbooks were analyzed for content, sequence of materials and type of practice problem.

3. Entry Behaviors. An empirical assessment of the skills and performance level of students represented the entry behaviors. From these results gaps and deficiencies were revealed. Sets of problems were also presented in conventional settings and sample students were asked to solve them. They were assisted until a successful answer was obtained. The approach was found to be successful in focusing on problems faced by students and helped to eliminate much material which seemed necessary by prior reasoning by the professors and the research staff.

4. Behavioral Objectives. The information obtained from course analysis, task analysis and entry level performance was used to formulate behavioral objectives. These were treated as hypothesized propositions which could be achieved by students given effective instructional material. Each objective was in turn broken down into prerequisite skills and concepts.

5. Instructional Strategies. Each assignment was followed by a detailed CAI quiz. If the student failed to meet the criterion performance he was given remedial assignments and recycled through the quiz items. Concept films and laboratory film presentations were also assigned quiz items.

6. Media Assignment. In media selection the following guidelines were used when attempting to facilitate acquisition of conceptual material, first, the use of multiple sensory channel inputs was maximized. Second, for the acquisition and problem solving the information was focused within restricted sensory channels. Third, when problem solving skills for long term retention was required the CAI drill and practice was maximized. Fourth, evaluation of attainment of behavioral objectives was based upon student performance during the CAI portion.

7. Field Tests. The materials were tried out on a sample of students who varied with respect to aptitude, prior knowledge and other psychological consideration. Interviews were held and the comments were used to revise the materials.

B. Empirical Iterative Solutions. Dr. Launor F. Carter[27/] of The System Development Corporation in reviewing its studies of comparisons of different response modes, different frame designs, different learning reinforcement procedures, different teacher roles and different sequencing methods concluded that while the studies have often yielded statistically significant results, from a practical point of view the findings were unimportant. The most important determinant of effective learning, he says, was the quality of the teaching material. Further, Carter concluded that unless the material had been tried out following an "engineering

approach" it usually proved ineffective. Carter says that it became apparent that effective materials were not produced by a priori hypothesis-testing experiment. Instead an interactive empirical procedure was more effective in producing instructional material. The researchers began with the selection of seemingly high-quality initial versions of self-instructional programs in reading, arithmetic, geometry and Spanish. Successive revisions were made until the improved versions were developed which produced the desired standards of performance. The procedure for developing the materials was as follows. A set of materials was tried with one child at a time. If the child made sufficient errors to warrant assistance the experimenter stopped the child and tried to determine the difficulty and attempted to remedy it by a variety of tutorial techniques. The experimenter then recorded the tutorial technique which seemed most effective. This process of modification was continued until sufficient data were accumulated to warrant a revision of the material. The new version was then tried on other children and again subsequent revisions were made. The data on revisions were analyzed for consistencies and patterns. Eventually, three hypotheses evolved. First, the "gap hypothesis" lead to the explicit inclusion of items necessary to develop prerequisite skills or new skills necessary for criterion performance. For example, they found that

in the reading program that they had assumed that if children practiced discriminating between word pairs they would quickly induce the appropriate letter-sound relationships. This did not happen and the investigators had to fill the gap by explicitly developing material with letter sounds which had to be included in the program. They also found that when children learned to sound out and read words in the program they still could not read novel combinations of the same word elements in the criterion test. This gap had to be filled by including and permitting students to practice on novel combinations.

Second, "the irrelevancy hypothesis" lead to eliminating items that were unrelated to the criterion test. They found that irrelevant items were distracting and that their elimination improved performance.

Third, "the mastery hypothesis" assumed that the student should not be permitted to move on to subsequent topics until he mastered the present one. When the child faltered, he was branched back and given more practice until he completely mastered the element.

The researchers conducted an independent experiment with a different set of materials and new students. The new experiment confirmed the importance of the hypotheses in that by removing the improvements in the effective programs there was a corresponding performance decrement.

The technique of successive empirical iteration of each segment until specified objectives are achieved is quite effective and quite different from the more conventional procedure of building a complete instruction package before evaluating it.

C. Regional Networks. Colleges in general do not have the financial resources to support a computer for educational purposes. Frequently the programs developed at one institution cannot be used at another because of language or equipment problems.

In 1968 the National Science Foundation established ten regional computer network experiments.[28/] The centers were created to serve as models and to attempt to assess the role and costs of computing activities. The ten regional centers connect 85 institutions of higher education and 22 secondary schools. They provide computing capacity, work with members to develop computer oriented curricula, and train faculty in their own and member institutions in the uses of computers in education. The original 10 regional centers were: Carnegie-Mellon University, Cornell University, Dartmouth College, Illinois Institute of Technology, University of Iowa, Oregon State University, Purdue University, St. Anselm's College, Southern Regional Education Board, and Stanford University. The following year five additional centers were added: California Institute of Technology, The University of Texas, Texas A&M, State University of New York at Buffalo and the Mid-Atlantic Educational Research Center (MERC).

The Illinois Institute of Technology (IIT) regional center is an example of one of the regional networks. IIT uses an IBM 360 Model 40 with a 2702 transmission control unit and ordinary telephone lines and teletypewriters to provide computing services to high schools, junior colleges and university students. A remote job entry system permits the use of a wide variety of peripheral equipment such as a card reader in the data preparation or a teletypewriter in the laboratory and can be used to communicate directly with the computer or through the more economical batch processing mode.

IIT has nine participating colleges and universities with about 1200 students which offer degrees in 15 fields in divisions of Natural Sciences, Social Sciences and Humanities. Each participating campus has a satellite teletype 33ASR installation with direct access to the IIT computer on the same priority schedule as IIT faculty and student on the IIT campus. Each campus also has four faculty members actively involved in designing and implementing course and curriculum materials. Curriculum is being designed in mathematics, biology, chemistry, physics, psychology, sociology, education and business management and economics.

The group leaders are to guide the participant schools in developing their courses and curriculum. They spent the summer of 1967 in surveying the uses of the computer in their disciplines and developing applications. They then visit each campus at least

once a semester to provide on-site assistance.

Since the emphasis of the IIT regional computer is on the enhancement of each cooperating college's curriculum a four step plan was devised. First, computer programming was introduced at each campus. Although most schools offered computer programming, the effective use of the network required that they possess an understanding of the languages available through the network and how to use their remote terminal. Faculty members were selected from each campus to attend a summer seminar. On returning to their campus they assisted other faculty members in developing courses and seminars for both the faculty and the students. Assistance was also provided from IIT on an as-needed basis. Second, course development was begun. The six academic group leaders visited each campus to talk to faculty and then devised programs for course enrichment. During the first year they completed the adaptation of a statistical package, a business game and a number of programs written in BASIC.

Third, curriculum development was to proceed from the selective introduction into a few courses the first year to wide spread use throughout the curriculum in the second year. The fourth and final step is evaluation. The evaluation will include interviews with faculty and students on each campus as well as by level.

While the fifteen regional computer centers have yet to be evaluated, they do represent a significant beginning toward bringing computer capacity and curriculum to a wide segment of American education.

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